

Use of GPS and Sensor-based Instrumentation as a Supplement to Self-Report in Studies of Activity and Participation.

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ABSTRACT

To obtain more accurate quantitative results when monitoring people's daily activities we have developed a passive data monitoring system. This Wheelchair Activity Monitoring Instrument known as the WhAMI uses odometers, tilt and seat occupancy sensors, and a Global Positioning System (GPS) to gather information about wheelchair users' daily activities. The purpose of this pilot study was to develop and test the WhAMI. Thus far, we have completed data collection on 3 subjects. Our results demonstrate that data from the WhAMI accurately describes the subjects' community travel, indoor mobility, and use of the tilt-in-space feature. The WhAMI is a valuable tool for collecting this quantitative data, and is designed to be used in combination with self report surveys to paint a complete picture of a subject's activity and participation.

KEYWORDS

Activity monitoring, power wheelchair, GPS, Datalogger

BACKGROUND

Information about people's daily activities is often collected with observation and self report measures such as diaries and surveys. These are valuable techniques, but they have many limitations. The need for the subject to keep up with a diary or participate in lengthy interviews can be burdensome while the need to encode the obtained data and conduct interviews is a burden for researchers. Furthermore, it is likely that subjects will misestimate quantitative data such as distance traveled in a car or time seated in a wheelchair. For example, it has been shown that in studies pertaining to automobile travel, people tend to underestimate the number of trips made, but overestimate the length of the trips (1).

An alternative method to monitoring people's daily activities is passive sensor-based monitoring. This technique can be used to overcome many of the limitations of self-report measures. Accelerometer-based physical activity monitors have been demonstrated to accurately record levels of physical activity over long periods of time for ambulatory populations (2). While researchers have begun to look at measuring physical activity of manual wheelchair users with commercial data loggers (3), the value of commercial physical activity monitors in measuring wheelchair use and community participation for power wheelchair users has not been addressed. Research has also shown that results from GPS when used with an ambulatory population tended to be highly accurate in number and length of trips, more so than self-report measures. However, GPS has also not yet been tested on the power wheelchair population.

The goal of this pilot study was to develop and test instrumentation (the WhAMI) that can passively address the following research questions.

- How active were subjects within the community?
- How much did subjects use their wheelchairs daily?
- How often and for how long do subjects use their specialized features such as tilt in space?

We are developing the WhAMI for use in future studies which combine the WhAMI with self-report measures to fully describe wheelchair use, activity, and community participation. We hypothesized that

the use of the WhAMI in addition to self report measures will provide accurate quantitative answers to these questions.

METHODS

To pilot test the instrumentation, we recruited subjects who were between the ages of 18 and 60, used a power wheelchair as their primary means of mobility and were in good health. All subjects signed an informed consent form (ICF).

Subjects' wheelchairs were instrumented with the WhAMI. Sensors on the WhAMI included wheel revolution counters that determine the distance and time of travel in the wheelchair, seat occupancy sensors that report when the subject is seated in the wheelchair and tilt meters that measure the position of the seating system. The collection of data was controlled by custom software running on a LP3500 single board computer from Zworld (Davis, CA). A GPS receiver and logger (Geostats, Inc, Atlanta) determined the subjects' travel within the community.

Data was collected for between one and two weeks at one second epochs. After the instrumentation was removed, the data was downloaded and analyzed by several custom programs created by CATEA and GeoStats. The analysis is performed based on definitions of events such as trips, bouts of mobility, and use of tilt features. We calculated these parameters from the data to answer several research questions, including: number of trips within the community, distance traveled outside the home, distance wheeled, number of bouts of mobility, time seated in wheelchair, number of tilts performed and time spent at different tilt angles.

In addition, GPS data are synched to Geographic Information System (GIS) information. This combined activity information can be used to identify habitual destinations. Maps are created that depict trips and locations, and are incorporated into web-based GPS Recall survey within which subjects can enter specific information about the depicted trip.

RESULTS

Table 1 shows the parameters measured by the WhAMI. GPS is only reported for two subjects as the receiver malfunctioned in one case. Time in chair data could not be obtained for subject P14 due to a seat occupancy sensor that was not optimized for the subject's extremely low weight. These problems have been addressed and will not be a concern for future subjects. In a general sense, the WhAMI data offers useful information such as the fact that P011 and P014 traveled 100% more than P013. P011 exhibited more of a routine in the data collection period than P013, as visible by the number of hours spent in the chair. For both P013 and P014, there was huge variability in the distance of trips.

Table 1 Goes Here

Only subjects P013 and P014 had a tilt feature available on their wheelchair. Subject P011 accurately showed that he did not perform any tilts during the study. Interestingly, subject P014 also did not perform any tilts during the study. Subject P013, however, performed an average of 5 tilts per day. A histogram showing how his chair was positioned on average is displayed in Figure 1.

Figure 1 Goes Here

Figure 2 shows an example of a GPS map complete with location designations. This map depicts a trip between Shepherd Center and the subject's home and illustrates how geographic locations and streets can be depicted.

Figure 2 Goes Here

DISCUSSION

The results illustrate that a significant amount of activity information can be collected by the WhAMI. This information includes general quantification of activity variables, but also includes visual information on excursions within the community. This type of information can be supported by subject interviews to collect a clear picture of activity and participation.

There are several limitations that are inherent in the use of instrumentation to study behavior of research subjects. First, although subject burden is reduced, and much of the encoding and collection of data is automated, a significant amount of effort is required before the study takes place to design and test such instrumentation and the software to understand the data. The variability of people and wheelchairs adds to this problem by requiring that instrumentation be both flexible and robust. Another major limitation is that although the instrumentation can answer questions such as when and how much accurately and specifically, it can never determine the motivation or importance behind the action. This is why self-report will always need to accompany instrumentation.

Despite limitations, the benefits of data loggers as a research tool are many. The burden of keeping diaries and reporting events in interviews can be drastically reduced. Diaries become totally unnecessary, and interview times are cut significantly because many of the questions that would have been asked are already answered. Recall of trips in the community is aided by the visual presentation of the trip accompanied with time markers that can detail stops made along the way. The second benefit is that results are more accurate than could ever been hoped for with traditional self report (1).

The potential of the WhAMI permits consideration of other applications for this type of system. One obvious application is to validate self report measures in research studies. This could help overcome some challenges in self reporting such as forgetting, and miscalculation. Another research related application would be to provide qualitative results where they are needed. Finally, with the proliferation of activity monitors being marketed to the general public as a personal tool to assist with health and exercise, it would seem to follow that a device such as the WhAMI could be used by wheelchair users as a personal tool for monitoring their own health and activity.

REFERENCES

1. Wolf, J., M. Oliveira, and M. Thompson (2003). The Impact of Trip Underreporting on VMT and Travel Time Estimates: Preliminary Findings from the California Statewide Household Travel Survey GPS Study. Published on CD-ROM of the Proceedings of the 82th Annual Meeting of the Transportation Research Board. Washington, DC.
2. Westerterp, KR (1999). Physical activity assessment with accelerometers. *International Journal of Obesity*, 23, S45-S49
3. Washburn, Richard A., Copay, Anne G. (1999). Assessing Physical Activity During Wheelchair Pushing: Validity of a Portable Accelerometer. *Adapted Physical Activity Quarterly*, 16, 290-299

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Table 1: Summary of Mobility Results

	P011	P013	P014
GPS – Number of Trips	n/a	14 trips in 9 days	30 trips in 14 days
GPS – Trip Distances	n/a	5.2±5.0mi (0.2-14.8)	3.6±3.93 mi. (0.2-18.1)
Wheeling Distance	1.3 ± 0.6 miles / day	0.1 ±0.2 miles / day	1.3 ± 0.6 miles / day
Time Spent Wheeling	62 ± 27 min / day	13 ±13 min / day	108 ± 24 min / day
Number of Mobility Bouts	99 ± 40 bouts / day	35 ± 27 bouts / day	224 ± 29 bouts / day
Time In Chair	13.5± 1 hours / day	6.5 ± 5 hours / day	n/a

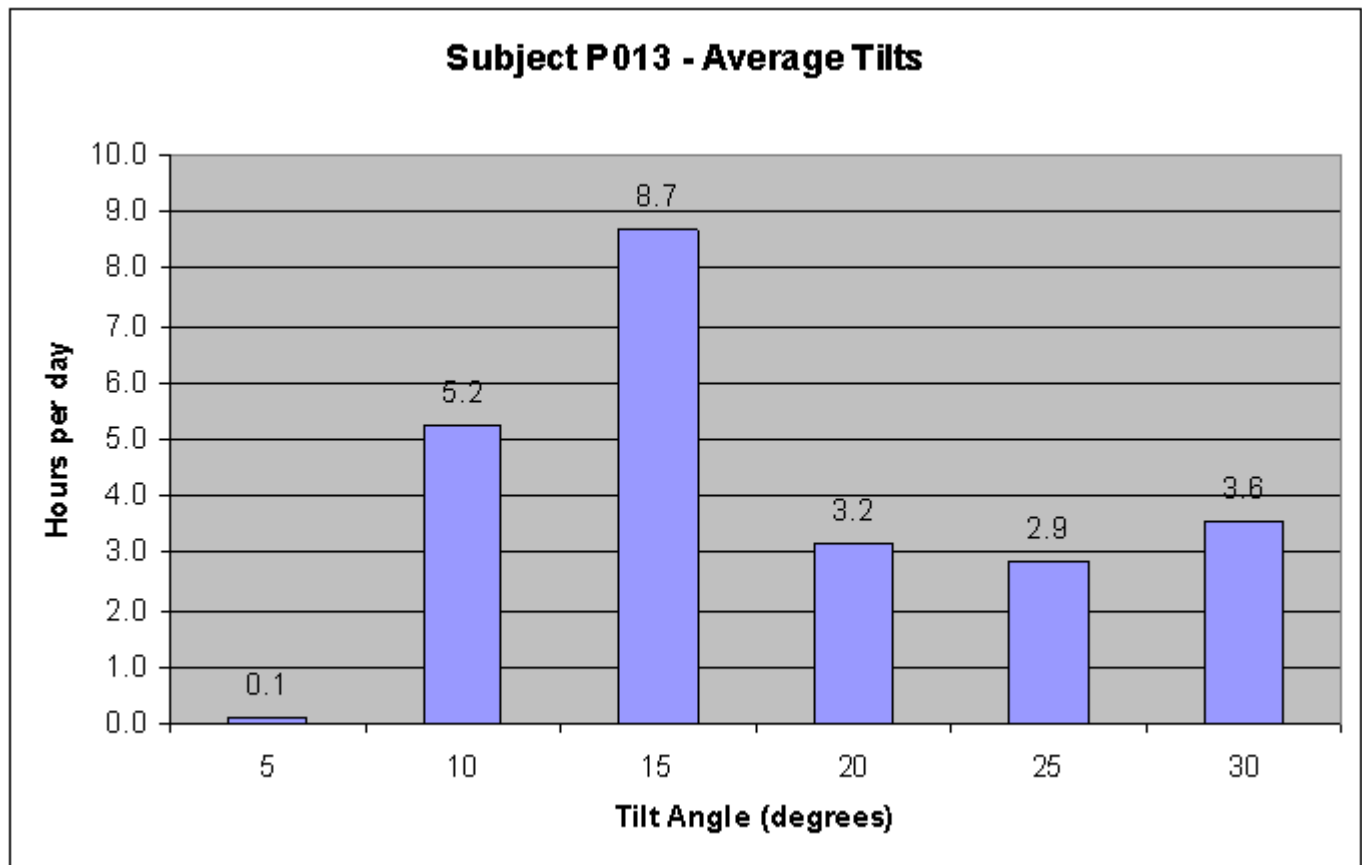




Figure 2: An example of GPS data showing a subject's trip between the Shepherd Center and their home.